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THE INFLUENCE OF THERMOMECHANICAL PROCESSING ON THE MICROSTRUCT--ETC(U)
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"The Influence of Thermomechanical Processing on the Microstructure of Metastable β-Ti Alloys"

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Carnegie-Mellon University
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THE INFLUENCE OF THERMOMECHANICAL PROCESSING ON THE MICROSTRUCTURE OF METASTABLE β-Ti ALLOYS

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INTRODUCTION

The class of Ti alloy known as metastable β-phase alloys have the potential for developing excellent strengths in thick sections while retaining good fracture resistance. There are several metastable β-phase alloy compositions which are now popular in the U.S.. Included in these is the alloy Ti-11.5Mo-4.5Sn-6Zr known as β-III. This alloy is somewhat leaner in β-phase stabilizing elements than other alloys such as Ti-3Al-6Cr-8V-4Zr-4Mo (Beta 'c') or Ti-8Mo-8V-2Fe-3Al (8-8-2-3). Consequently, β-III can form ω-phase which is undesirable because of its embrittling tendencies. This study has been initiated to demonstrate that appropriate thermomechanical working operations can be used to impart excellent age-hardening characteristics to β-III while avoiding ω-phase formation. Thus, when properly processed, β-III can exhibit a more rapid aging response than Beta 'c' or 8-8-2-3 but without the attendant formation of ω-phase.

MATERIALS AND PROCEDURES

We have examined a heat of β-III with the following composition by weight:

Mo	Sn	Zr	O_2	H_2	N_2	C	Fe	Ti
11.60	4.94	5.72	0.164	0.0082	0.009	0.022	0.05	bal.

The starting material was in the form of plate approximately 20 mm. thick. This plate was then hot worked to a $\sim$ 40% reduction in thickness following one of two schedules. The first schedule employed a starting temperature of 760°C (1400°F) and a four pass rolling operation with a finishing temperature of <650°C (<1200°F). This material is designated B-1 hereafter. The second schedule employed a starting temperature of $\sim$ 750°C ($\sim$ 1300°F) and a four pass isothermal rolling sequence, with a 5 min. reheat between passes. This material is designated B-2 hereafter. The final gage of each of these two materials was: B-1, 12.3 mm.; B-2, 12.5 mm. These materials were then aged for varying times at $\sim$ 425°C (800°F), $\sim$ 468°C (875°F) and $\sim$ 510°C (950°F). Vickers hardness, light metallography, and thin foil transmission electron microscopy (TEM) were then performed on selected samples to correlate hardening response with microstructure.

RESULTS AND DISCUSSION

The different thermomechanical treatments, (TMT's), B-1 and B-2 produced final products with significantly different microstructures, and hardening responses during subsequent aging below the working temperature. The first of these observations is illustrated in Figure 1 which shows optical and electron transmission micrographs of both materials in the as hot-rolled condition. The most striking difference is the partial recrystallization of B-2, as evidenced by large, clear β-grains (Figure 1(a)), and the differing amounts and size of the primary α which forms during the hot working, reheating, and subsequent cooling from the working temperature.

Both materials are effectively worked below the β transus temperature of $\sim$ 745°C (1375°F). The ability of the B-2 material to partially recry-

stallize results from the increased holding time at working temperature for this condition. The B-2 material also exhibits a smaller volume fraction of the α-phase, as well as large α-particles (compare Figure 1(c) with 1(d). This can be rationalized by the decreased density of dislocations and dislocation sub-structure in B-2 as compared to B-1.

As a result of the more uniform and increased defect density in B-1, its hardening response is greater than B-2 during aging at 875 and 950°F as shown by the hardness versus time curves of Figure 2. This agrees with the suggestion (1) that an increased defect density promotes nucleation of α-phase during aging and therefore a finer α-particle size.

As discussed, the higher maximum hardness in B-1 results from the small α-particle size and high volume fraction, as illustrated in Figure 3. These particles are still quite large, so that it is unlikely that the material is in its peak hardness condition.

Aging β-III at 800°F usually results in ω-phase formation (2). However, TEM studies on both B-1 and B-2 revealed that only α-phase had formed. Thus, the presence of a high density of nucleation sites can completely suppress ω-phase formation, at least for the aging times we have examined. Since ω-phase is a serious embrittling agent, TMT plus aging appears to be a desirable technique for achieving high hardness without incurring undue brittleness. A similar suggestion has been made by Rosales and Summer (1).

ACKNOWLEDGEMENTS

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REFERENCES

1. Rosales, L. A. and Summer, A. W., "Strengthening of beta titanium alloy", Report No. NA-73-191, North American Rockwell (7 March 1973).

2. Williams, J. C., Hickman, B. S., and Marcus, H. L., "Effect of omega phase on the mechanical properties of titanium alloys", Met. Trans., vol. 2, p 1913 (1971).

LIST OF FIGURES

Figure 1. The microstructures of B-1 and B-2, in the as hot-rolled condition; a) and c) are B-2, b) and d) are B-1.

Figure 2. Hardness versus aging time for the three aging temperatures shown.

Figure 3. Microstructure of B-1 after a 60 min. aging treatment at 800°F.

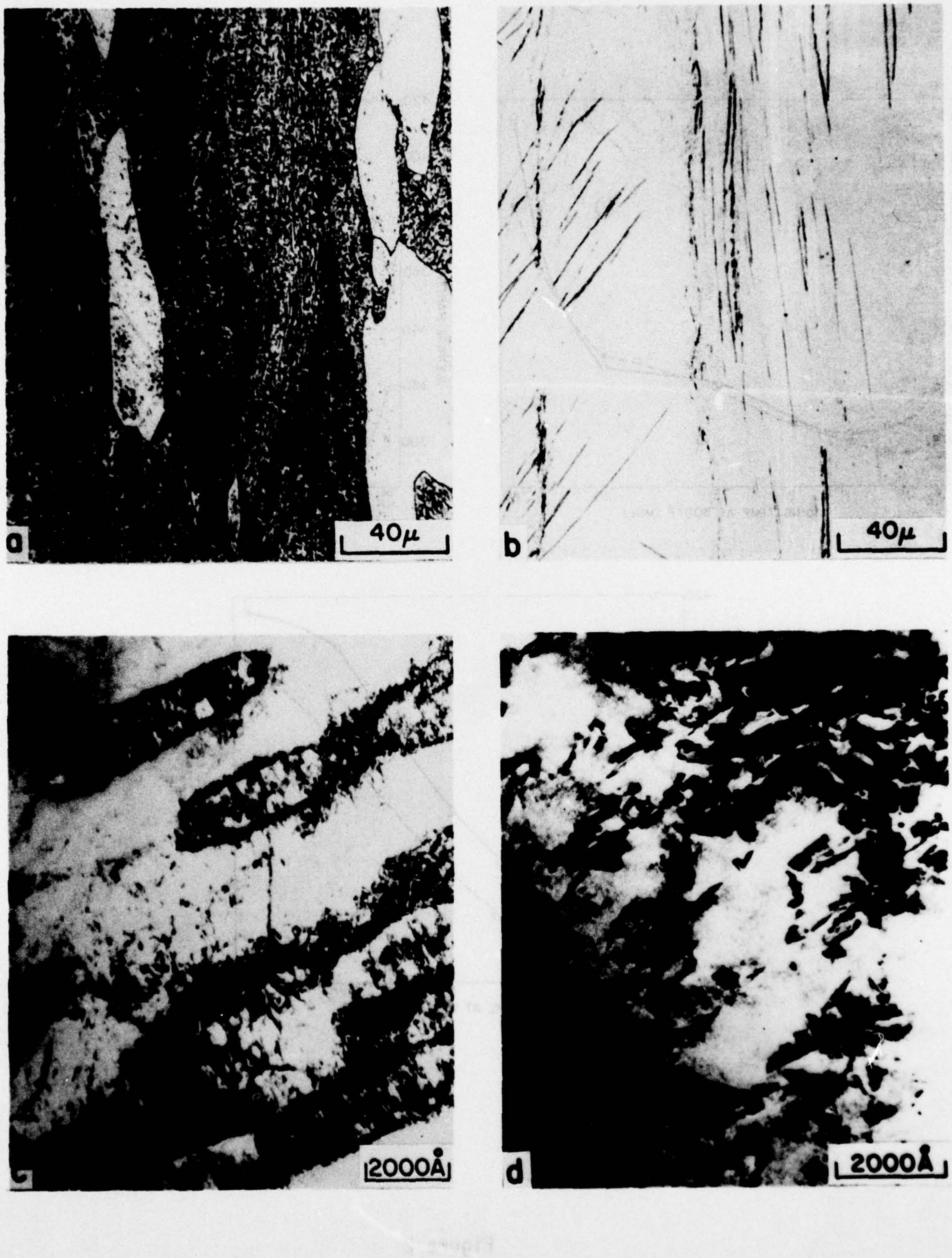
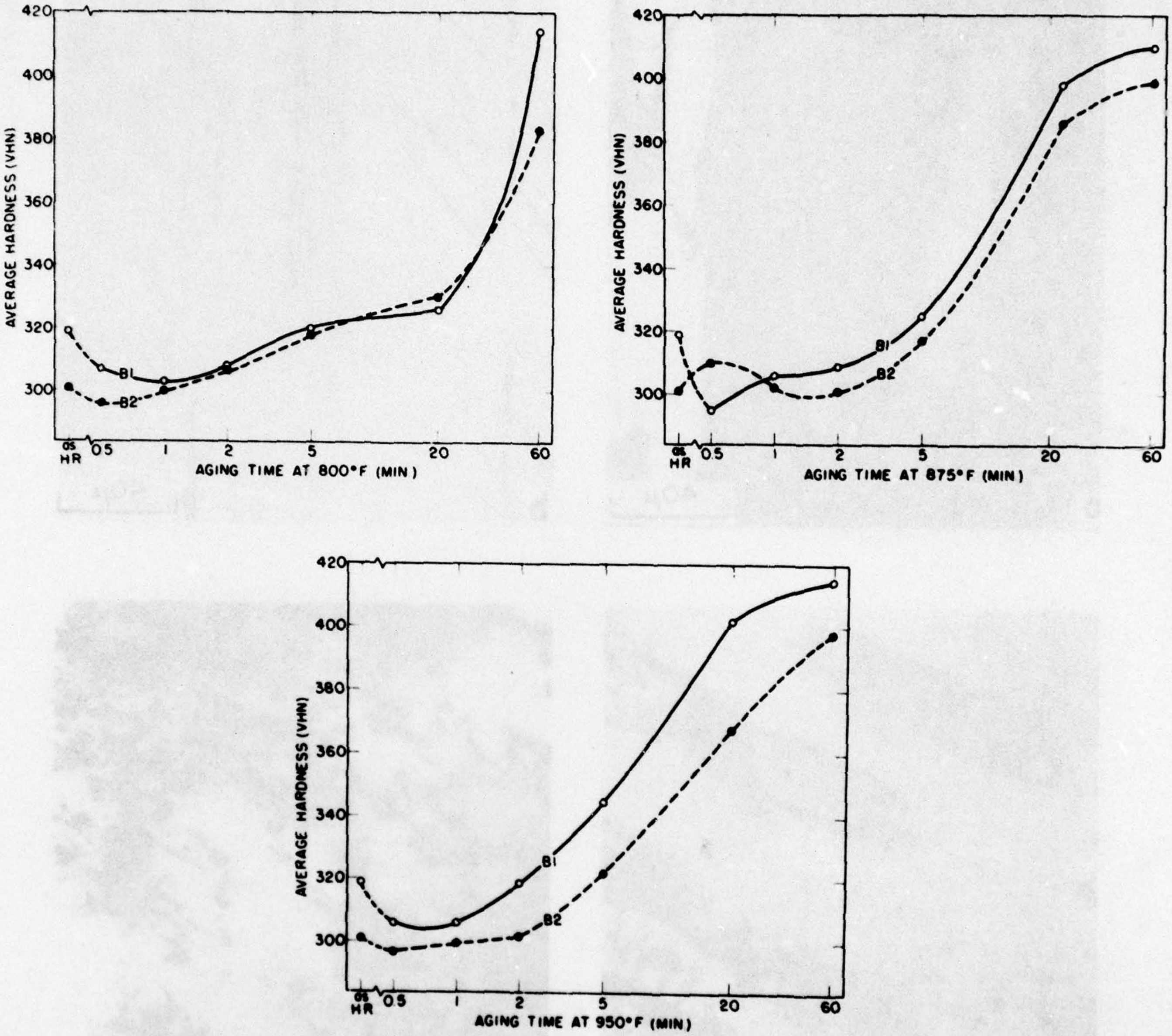


Figure 1



420
400
380
360
340
320
300
AVERAGE HARDNESS (VHN)
AS HR
0.5
1
2
5
20
60
B1
B2
AGING TIME AT 800°F (MIN)
AGING TIME AT 875°F (MIN)
AGING TIME AT 950°F (MIN)

Figure 2

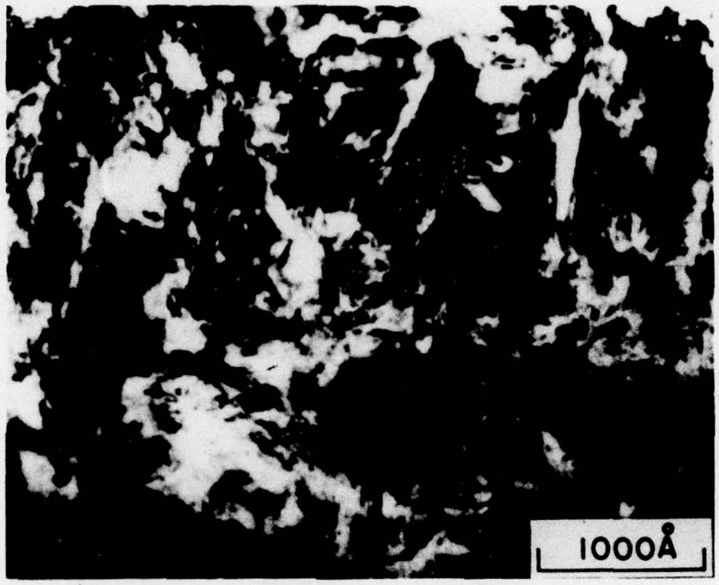


Figure 3

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13. ABSTRACT

This paper describes the effect of working history on the subsequent microstructure and hardness variations during aging of Ti-11.5Mo-6Zr-4.5Sn. Two different thermomechanical processing schemes were used to vary the percent recrystallization and dislocation density of the metastable bcc phase. These samples were then aged at different temperatures for varying times and the increases in hardness were monitored using Vicker's hardness measurements. Significant differences in hardening response were observed depending on whether the working of the material was completed well below or at the β-transus. Transmission electron microscopy was used to correlate the age hardening response with microstructure. Significant differences in primary α distribution were detected in the as-hot-worked materials processed by the two different schemes and these differences helped to account for the variations in age hardening response. In both materials, it was shown that sufficient heterogeneous nucleation sites in the form of dislocations were present to promote direct nucleation of α-phase, thereby eliminating the embrittling ω-phase.

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omega

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